ACEA

CAFE

CFC

CNG

CO

CO_2

EU

HC

I/M

IPCC

LPG

N_2O

NMHC

NO_x

NTE

OBD

PM

PNGV

ppm

R&D

SUV

U.S. EPA

ZEV

Bellagio Memorandum on Motor Vehicle Policy

Principles *for* Vehicles *and* Fuels *in* Response *to* Global Environmental *and* Health Imperatives

Consensus Document: 19–21 June, 2001

Bellagio, Italy

The Energy Foundation

A/F	*Air-Fuel Ratio*
ACEA	*European Car Manufacturer's Association*
CAFE	*Corporate Average Fuel Economy*
CFC	*Chlorofluorocarbons*
CNG	*Compressed Natural Gas*
CO	*Carbon Monoxide*
CO_2	*Carbon Dioxide*
EU	*European Union*
HC	*Hydrocarbons*
I/M	*Inspection & Maintenance*
IPCC	*Intergovernmental Panel on Climate Change*
LPG	*Liquefied Petroleum Gas*
N_2O	*Nitrous Oxide*
NMHC	*Non-Methane Hydrocarbons*
NO_x	*Oxides of Nitrogen*
NTE	*Not-to-Exceed*
OBD	*On Board Diagnostics*
PM	*Particulate Matter*
PNGV	*Partnership for a New Generation of Vehicles*
ppm	*Parts Per Million*
R&D	*Research & Development*
SUV	*Sport Utility Vehicle*
U.S. EPA	*United States Environmental Protection Agency*
ZEV	*Zero Emission Vehicle*

Acknowledgements

The conclusions in this report, reached by consensus of the regulators and experts gathered at Bellagio, represent an enormous commitment of time and thoughtfulness by the participants. Our first acknowledgement, then, is to our colleagues who spent the time together hard at work building this document.

Second, we want to thank the Rockefeller Foundation for providing the splendid Bellagio Study and Conference Center for the meetings. The peace, isolation, and splendor of Bellagio proved a constant inspiration for our work. In particular we would like to thank Mrs. Celli, the director of the center, for her work in ensuring that the meeting ran flawlessly.

Finally, we would like to thank Michael P. Walsh, who prepared an extraordinary paper comparing international approaches to regulating fuels and automobiles to give participants common background for the meeting. We would also like to thank Mr. Walsh for taking the lead on the rationale section of this memorandum.

Hal Harvey, President
Charlotte Pera, Transportation Program Officer

Contents

The principles presented in this memorandum were developed by consensus and represent the collective expert opinion of the individuals participating in the meeting. They do not necessarily represent the views of any participant's organization or government.

Automobile manufacturers and oil companies are the quintessential global companies. They manufacture and sell their products in hundreds of countries, specializing where necessary, but always seeking economies of scale.

But they face regulations that are different—sometimes vastly different—in dozens of key countries. In some jurisdictions, for example, public officials have put a high priority on energy efficiency; in others, conventional pollutants are emphasized. Some countries still allow leaded gasoline, while others are pushing toward zero emissions of any pollutant.

This patchwork regulation, inconsistent in both means and goals, leaves hundreds of millions of people without the benefit of the best systems to reduce pollution and energy waste, and imposes profound health, environmental, and economic costs on the citizens of many nations. Furthermore, it costs auto and oil companies billions of dollars as they design different products for different regulatory systems.

With this dysfunction in mind, the Energy Foundation gathered leading regulators and experts from Europe, China, Japan, and the U.S. for an intensive, three-day meeting to synthesize the best regulatory models for cleaning up cars, trucks, and other motor vehicles.

The result, described in this document, has far-reaching implications. It represents a consensus of all 18 participants on over 40 principles —or guidelines—that, taken together, should constitute the policy future for motor vehicles and transportation fuels. These principles can form a clear, explicit guide for policymakers around the world and for automakers and oil companies as they design their products for the next decade.

The Bellagio Memorandum on Motor Vehicle Policy comprises four sections: a preamble, a categorized list of all 43 principles, a rationale section which briefly discusses each principle, and a short concluding section on next steps. Readers are, of course, encouraged to read the entire memorandum, but readers with very limited time might start with the third section of the preamble, titled Scope and Summary of Principles.

"We need to have government recognize that harmonization...allows freer movement in an increasingly more global automotive market. We've found through studies that even if you harmonize standards up*, the cost savings and benefits are incredible."*

Alliance Supports Cleaner Cars
Josephine Cooper
President, Alliance of Automotive Manufacturers
Synopsis of Panel Presentation at 2000 Future Car Congress, Washington, DC

Urgent Need for Cleaner and More Efficient Vehicles

Growth in motor vehicle production has been dramatic in the last several decades; the number of new vehicles produced per year worldwide has risen from about five million just after the Second World War to nearly 55 million today. As a result of expected growth in population and gross domestic product, the next few decades will see strong growth in the worldwide vehicle fleet, especially in the rapidly industrializing countries of Asia. This growth is overtaking what are otherwise very successful efforts in many countries to reduce vehicle emissions.

Global emissions of all pollutants from on-road vehicles are projected to be substantially higher in 2030 than they are today. For non-OECD[I] countries, emissions of all pollutants are growing very rapidly and are projected to be three to six times higher in 2030 than in 1990 unless strong control programs are implemented.[2]

This growth in vehicle emissions is of great concern to governments as they strive to protect public health and welfare. The harmful effects of conventional pollutants from motor vehicles–hydrocarbons, oxides of nitrogen, carbon monoxide, and particulates–on human health and ecosystems are well documented, and scientific evidence continues to grow. Evidence of the serious health impacts of toxic air emissions[3] from motor vehicles also is increasingly compelling.

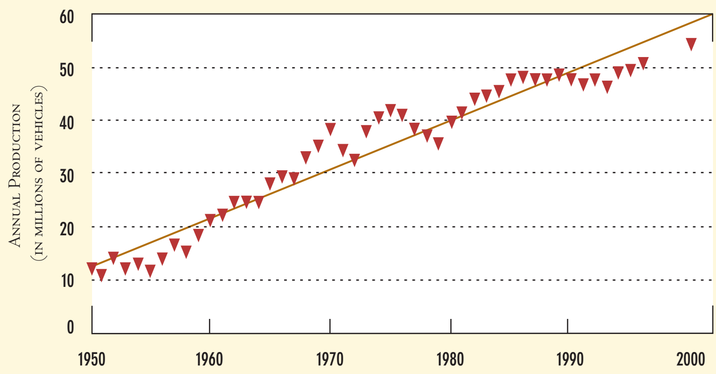
Greenhouse gas emissions from motor vehicles present longer-term problems, potentially with severe health, environmental, and economic consequences[4]. In most countries, over 90 percent of the global warming potential of the direct-acting greenhouse gases from the transportation sector comes from carbon dioxide. The transportation sector is responsible for about 26 percent of global carbon emissions, and the International Energy Agency projects that the transport sector emissions will rise by 75 percent between 1997 and 2020. Reducing transport sector carbon emissions will therefore be crucial for stabilizing atmospheric concentrations of greenhouse gases.

Other environmental problems associated with the transport sector include oil spills, acid rain, air and water pollution at refineries, and groundwater contamination from leaking underground storage tanks.

It is incumbent upon governments to reduce these harmful impacts of motor vehicle use. Because vehicles are long-lived and the world fleet continues to grow, programs, if they are to be truly effective, must address the in-use fleet, the next-generation fleet (those new vehicles that will be sold over the coming several years), and the fleet of the future, which will depend largely on today's research and development programs as well as on long-term policy signals. The principles in this document are aimed at all three "fleets."

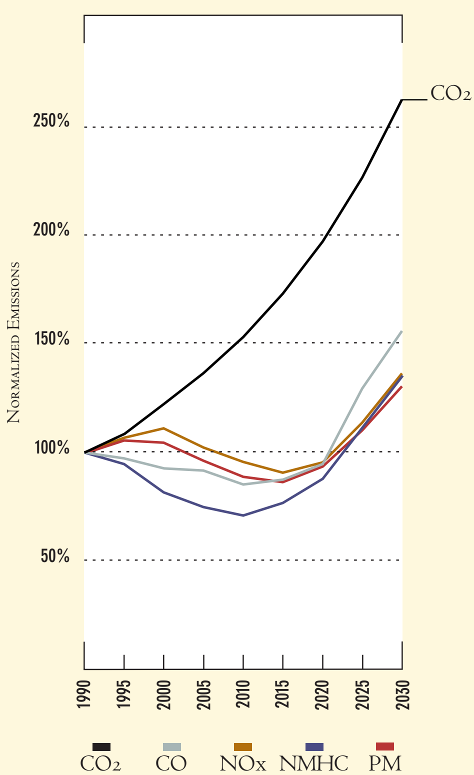
The rationale for the principles, presented in this memorandum, provides additional information on the harmful effects of motor vehicle emissions.

Trends in Motor Vehicle Production



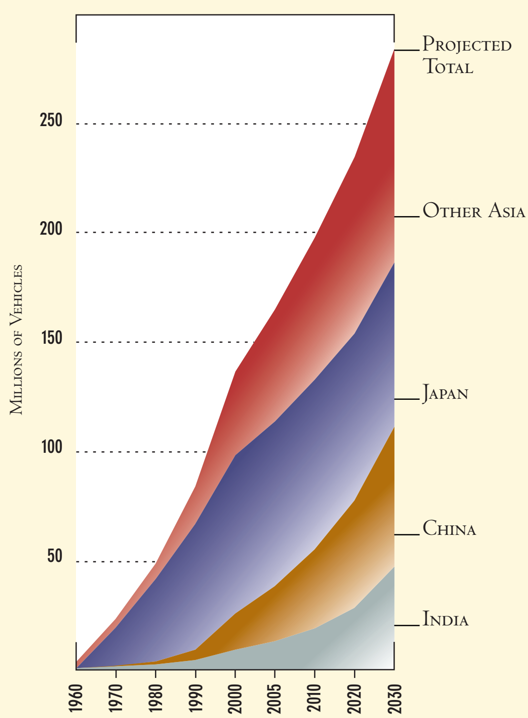
Source: Michael Walsh, www.walshcarlines.com

Global On-Road Vehicle Emissions



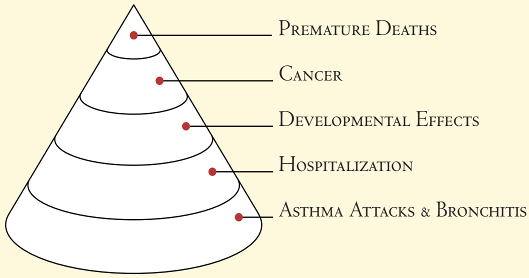
Source: Michael Walsh, www.walshcarlines.com

Projected Vehicle Population in Asia



Source: Michael Walsh, www.walshcarlines.com

Health Effects of Air Pollution



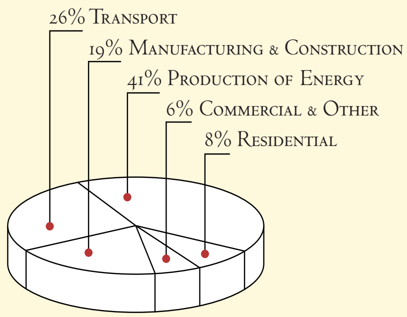
Lancet Medical Journal Study

In Austria, France, and Switzerland:

- *About 6% of all deaths, about 40,000 per year (twice the annual deaths from traffic accidents), are due to outdoor air pollution.*
- *Vehicles are responsible for about half of this total.*
- *People in cities die about 18 months earlier than they otherwise would.*
- *Each year, outdoor air pollution causes over 25,000 new cases of chronic bronchitis; 800,000 episodes of asthma and bronchitis; 16 million lost person days of activity per year.*
- *Health costs from traffic pollution are about 1.7% of total GDP.*

Source: The Lancet, Vol. 356 Issue 9232 September, 2000, pp 792, 795

Global Greenhouse Gas Emissions



Source: IEA

Opportunities for Major Improvements

Although the environmental and health burden associated with motor vehicle use is pervasive and persistent, and the certain, rapid growth of the world fleet presents a tremendous challenge, there is cause for optimism. Both industrialized and developing nations have taken major steps in recent years to control vehicle emissions and improve efficiency. Strong programs in several countries have produced impressive emissions reductions and efficiency improvements over the last thirty years, indicating a similar potential for improvement in countries with younger programs. Emerging technologies, in combination with intelligent policies, offer hope for dramatic emissions reductions into the future. Car, truck, and engine manufacturers are bringing forward new technologies such as catalyzed particulate traps, continuously variable transmissions, lightweight materials, hybrid-electric drivetrains, advanced gaseous-fuel engines, and fuel cell vehicles. Battery-electric cars and mini-cars are finding niche markets. Refineries are beginning to produce reformulated, very low sulfur fuels that enable advanced emissions technologies.

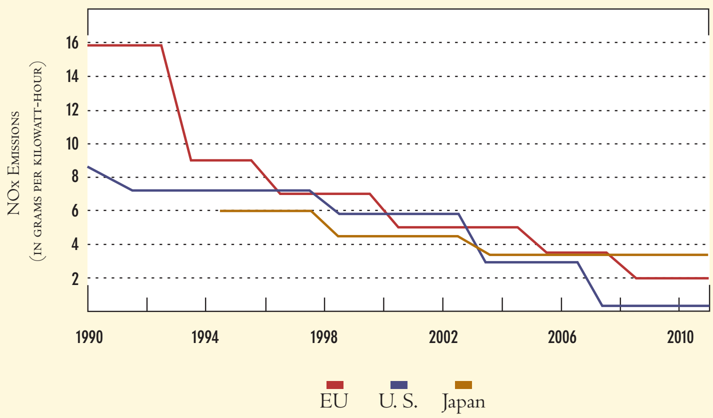
Consider: In many industrialized countries, new cars are certified to emit less than 10 percent of the emissions per kilometer driven of pre-catalyst cars. And the cleanest internal-combustion engine vehicles on the road today are certified to emit less than 10 percent of the emissions produced by average new cars[5]. As emissions standards tighten over the next decade, average vehicles will come closer and closer to these very low levels.

- The European Union has adopted stringent limits on the sulfur content of both diesel and gasoline (50 parts per million (ppm) maximum by 2005) and recently proposed a further shift to near-zero sulfur levels for both fuels (10 ppm maximum by 2011 or, possibly, sooner).
- The U.S. Environmental Protection Agency (U.S. EPA) recently adopted a rule that will reduce the emissions of new diesel trucks and buses by 90 to 95 percent from current levels by the end of this decade.

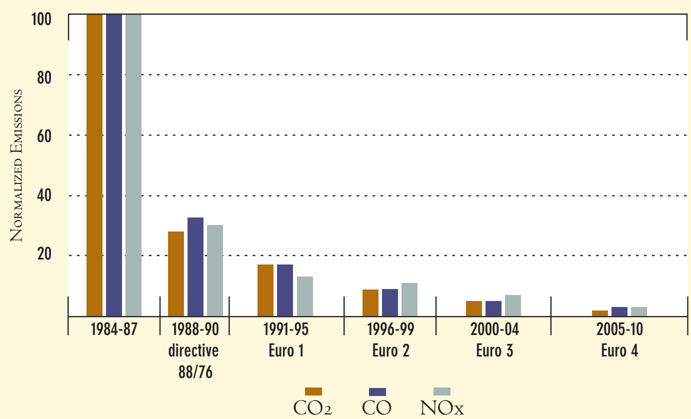
- Several developing countries, including China, Mexico, Thailand, and South Korea, appear to be on track to reach world-class vehicle emissions standards within the next decade.
- Over three decades of aggressive programs in California have greatly improved the air quality in the most polluted city in the U.S. –Los Angeles– which exceeded the U.S. standards for ozone pollution (smog) only 41 days in 1999, down nearly 80 percent from the late 1970's when the region saw excessive smog about 200 days each year.
- China has taken impressive steps to control motor vehicle emissions in the past few years, phasing out leaded gasoline nationwide, replacing several hundred diesel buses with new natural gas buses, and within a few years converting most of Beijing's on-road car fleet to catalyst technologies with a combination of new vehicle emissions standards, retrofits, and scrappage programs.
- The European Car Manufacturer's Association (ACEA) proposed, and the European Union accepted, a voluntary agreement to reduce "per-vehicle" greenhouse gas emissions by 25 percent from a 1995 baseline by 2008. This implies a 33 percent improvement in new vehicle fleet fuel economy.
- In Japan, the national government has established a series of weight-class fuel economy standards that require an approximately 23 percent improvement in the fuel economy of gasoline-fueled light-duty vehicles by 2010.
- Although they expect gasoline and diesel to continue to be the predominant vehicle fuels for many years, the major automakers and many leading oil companies are spending hundreds of millions of dollars developing fuel cell technology and exploring non-fossil fuels such as hydrogen.

Past success does not guarantee continued gains. Policymakers will need to show leadership, bolstered by strong science and informed vision, to ensure that future generations can enjoy personal mobility without paying a high price in disease, environmental degradation, and economic dislocation. Bellagio meeting participants drew on their knowledge of progress and problems to date, and their understanding of the opportunities and challenges posed by the future, in developing the principles described in this memorandum. We hope that these principles will give valuable guidance and begin to send a cohesive set of policy signals to the industries that produce vehicles and their fuels.

Heavy-Duty Engine NOx Emissions Standards

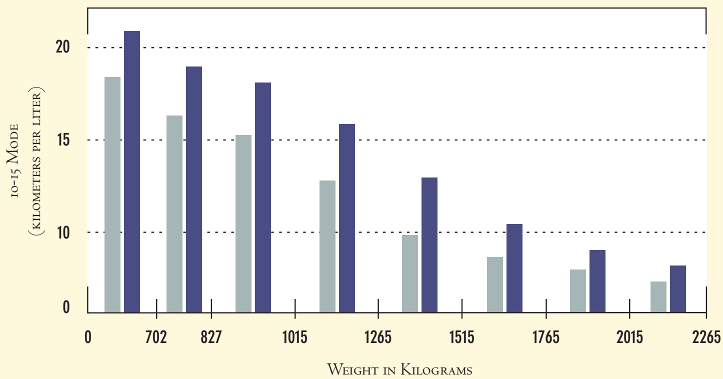


European Emissions Standards



Source: Michael Walsh, www.walshcarlines.com

New Japanese Weight Class Fuel Economy Standards



1995 Japanese Auto Manufacturer's Association (JAMA) Average

Regulation at 2010

Regulation requires percent increase over manufacturer specific baselines for each weight class.

Source: Japan Ministry of Transport

Scope and Summary of Principles

In June of 2001, a group of 18 experts met in Bellagio, Italy, to develop a set of principles for the next generation of government actions that will shape future motor vehicle technology. The group included top regulators and experts from China, the European Union, France, Germany, Japan, and the United States.[6]

The meeting focused on air emissions from road transport, including conventional and toxic pollutants as well as greenhouse gases. Non-highway mobile sources, including off-road equipment, ships, and aircraft were included in the discussions to a lesser extent, and the treatment of these sources in the principles is not comprehensive. Where the principles refer to "vehicles," they can be taken to apply to all types of vehicles, including cars, trucks, off-road equipment such as excavators or farm tractors, motorcycles, aircraft, tuk-tuks, and so forth, with two exceptions: principles number eight and nine in the section on conventional pollutants and toxics were discussed in the context of on-road cars and trucks only.

The principles presented in this memorandum were developed by consensus and represent the collective expert opinion of the individuals participating in the meeting; they do not necessarily represent the views of any participant's organization or government. Participants are listed in the next section.

The 43 principles were developed within five categories:

1. Overarching principles
2. Fuels
3. Conventional pollutants and toxics
4. Greenhouse gases
5. Advanced technology

Because there are natural links between these categories, a number of the principles are closely related, but none of the principles is redundant; each serves a unique purpose. It is important to note that the scope of the meeting was limited to principles guiding vehicle technology and fuel formulation. Meeting participants agreed that other methods for reducing emissions of air pollutants and greenhouse gases, such as increased use of alternative transportation modes (e.g., commuting by bus or bicycle instead of car) and travel-reducing land use development, although not addressed in these principles, are also crucial elements of any effective plan to reduce the environmental impacts of transportation.

Participants also noted that motor vehicles cause environmental problems beyond air emissions—noise pollution, for example. These problems must also be addressed to meet societal goals, and government programs to reduce vehicular air emissions should be designed to alleviate associated problems where possible. Because it was necessary to limit the scope of the Bellagio meeting, synergies between air emission reduction measures and measures to address other harmful impacts from motor vehicles are not explicit in the principles, except that noise reduction is included in two places.

Meeting participants recognized that programs to improve air quality and reduce climate change must be adopted by various political authorities around the world. Each government provides ample opportunity for decision-makers to consider competing priorities and seek balanced solutions. The Bellagio principles, therefore, do not preempt these processes by factoring in likely objections a priori. Participants did emphasize in discussion that cost-effectiveness should always be taken into account, and that policy-makers should strive toward a mix of strategies and implementation timelines that minimizes the cost of achieving program goals. Participants also noted that cost-effectiveness projections should be informed by experience; there is a compelling history of actual costs for new regulations being lower than costs projected by regulators and considerably lower than costs projected by to-be-regulated industries.[7]

Meeting participants agreed that tighter standards and better technologies for motor vehicles than are currently mandated or available are necessary for meeting public health and environmental goals, particularly as the world fleet continues to grow. And, because motor vehicles and their fuels are global products, participants believe that coordination between regulatory bodies around the world is needed to create a rational set of policies that will guide further development and distribution of these products, consistent with the expeditious pursuit of societal goals.

We encourage readers to examine each of the 43 principles. But, to simplify review, we offer a summary in the two numbered lists below.

The 43 Bellagio principles lead to the following eight broad lessons. Policymakers must:

1. Design programs and policies that reduce conventional, toxic, and noise pollution and greenhouse gas emissions in parallel, and ensure that future technologies provide major improvements in each of these areas.
2. Base policies solely on performance compared to societal objectives, and not give special consideration to specific fuels, technologies, or vehicle types.
3. In both industrialized and developing countries, expect and require the best technologies and fuels available worldwide; it is not necessary or cost-effective for developing nations to follow, step by step, the same path of incremental improvements that was taken by the industrialized nations.
4. Use combinations of economic instruments and regulatory requirements; make related policies complementary.
5. Treat vehicles and fuels as a system, and move toward standards based on life-cycle emissions (including vehicle and fuel production, distribution, and disposal) in policies.
6. Prevent high in-use emissions with more realistic and representative test procedures, greater manufacturer accountability, improved inspection and maintenance programs, on-board monitoring and diagnostics, and retrofit and scrappage programs.
7. Consider the relative cost-effectiveness of near-term measures and the market potential of future technologies.
8. Work across jurisdictions, both nationally and internationally, to strengthen programs and give cohesive signals to affected industries.

The principles that embody the most specific and urgent calls to action are:

1. Lead should be immediately banned in all fuels.
2. Near-zero sulfur (10 ppm or less) should be introduced in all fuels except residual bunker fuel.
3. Benzene levels in gasoline should be capped at no more than one percent worldwide. In addition, aromatic content should be controlled.
4. Emissions standards worldwide should be based on the best available technology.
5. Test procedures should reflect real-world operating conditions for all vehicles and engines.
6. Manufacturers should be responsible for in-use (real-world) emissions in normal use.
7. Measures to reduce greenhouse gas emissions from all vehicles (including at least 25 percent average reduction for new personal passenger vehicles over the next decade) should be adopted. Mechanisms could include 1) voluntary agreements with manufacturers, 2) fuel efficiency standards, 3) tailpipe greenhouse gas standards, and 4) financial incentives.

Participants will pursue tighter standards and better technologies in accordance with the principles described in this document. It must be recognized, however, that each jurisdiction has its own procedures and priorities, and that appropriate timetables for implementing the measures indicated in these principles will vary. Developing nations, in particular, have different constraints and opportunities than industrialized nations. China, for example, transitioning between a centralized and free market economy, entering into the World Trade Organization, and facing continued dramatic growth in its vehicle fleet, while still at very low per-capita vehicle ownership and with an underdeveloped fueling infrastructure, may forge a path to a cleaner and more efficient fleet that is more compressed than the path taken by Europe, the U.S., or Japan.

Bellagio meeting participants intend to promote annual evaluations of progress toward achieving the principles outlined in this memorandum. Participants also recommend collaborative evaluation of progress where action across jurisdictions is needed, such as worldwide phase-out of lead in motor fuels.

Participants

The meeting organizers attempted to include in this meeting representatives of nations at the forefront of motor vehicle production, consumption, and regulation. Of course, many nations with important automotive industries and unique regulatory challenges were not represented at the meeting. Efforts to increase information exchange and coordination among countries are ongoing, and the Energy Foundation expects that any follow-on meetings will include more countries.

Participants in the development of the Bellagio Memorandum on Motor Vehicle Policy:

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As mentioned previously, the principles presented here were developed by consensus and represent the collective expert opinion of the individuals participating in the Bellagio meeting; they do not necessarily represent the views of any participant's organization or government. This list of principles is repeated in the following section, with a rationale for each point.

Overarching Principles

1. Clean vehicle strategies should promote air quality (including air toxics) and greenhouse gas goals in parallel. Noise pollution should be considered as well.
2. Vehicles and fuels should be treated as a system.
3. New vehicle standards for greenhouse gas emissions and conventional pollutants should be fuel-neutral.
4. Policies should be based on full life-cycle emissions, including vehicle and fuel production, distribution, and disposal.
5. Cost-effectiveness should be considered in achieving the goals.
6. Economic instruments should be used to promote clean, efficient vehicles and fuels.
7. Policies for clean vehicles should be mutually re-enforcing, not conflicting. For example, economic policy should support mandatory standards.
8. Clean transportation strategies should promote inherently clean vehicles.
9. New vehicle industry in developing countries should be based on new technology, and not be a dumping ground for old technology.
10. The recommendations in this paper also include vehicles and fuels that are especially important for developing countries (mopeds, tuk-tuks, buses, etc.).
11. A truly effective program will require the active involvement of government at the national, regional, and municipal level.

Fuels

1. Lead should be immediately banned in all fuels.
2. Near-zero sulfur (10 ppm or less) should be introduced in all fuels except residual bunker fuel.
    a. Use longer time horizon, but stricter targets.
    b. Do in one step, not more.
3. Sulfur content in residual bunker fuel and heavy fuel oil should be significantly reduced worldwide, particularly in sensitive areas.
4. Benzene levels in gasoline should be capped at no more than one percent worldwide. In addition, gasoline aromatic content should be controlled.
5. Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), and other alternative fuels need clear content standards for environmental performance; these standards should be set at the beginning of a fuel's introduction.

Conventional Pollutants and Toxics

Standards

1. Emissions standards worldwide should be based on the best available technology.
2. Future new vehicle standards should be fuel-neutral.
3. Vehicles that perform the same function should be required to meet the same standards, based on the capability of the leader, not the laggard.
4. Vehicle standards and fuel standards should be linked.
5. Particulate emissions standards should be designed to reduce the number of particles as well as the mass.

Controlling emissions over the lifetime of the vehicles

6. Test procedures should reflect real-world operating conditions for all vehicles and engines.
7. Inspection and maintenance programs should be used to control lifetime in-use vehicle emissions. Programs should separate inspection from repair, and post-inspection diagnostics should precede repair.
8. On-board diagnostic systems that identify failure modes and store failure data should be required for all new vehicles.
9. On-board measurement with real-time logs should be required for all new vehicles.
10. Manufacturers should be responsible for in-use (real-world) emissions in normal use.
11. Regulators should focus on in-use testing of heavy-duty vehicles.

Upgrading the in-use fleet beyond what new vehicle standards and normal turnover can accomplish

12. Cost-effective retrofit programs should be established for all vehicles.
    a. Retrofit standards must be matched by appropriate fuel standards (e.g., low-sulfur, no-lead gasoline).
    b. Testing must be done to verify efficacy of retrofit programs.
13. Scrappage and other policies should be used to speed fleet turnover.

Greenhouse Gases

1. Measures to reduce greenhouse gas emissions from all vehicles (including at least 25 percent average reduction for new personal passenger vehicles over the next decade) should be adopted. Mechanisms could include 1) voluntary agreements with manufacturers, 2) fuel efficiency standards, 3) tailpipe greenhouse gas standards, and 4) financial incentives.
2. Reduction measures should be designed to avoid promoting increases in size, weight, or power.
3. Effective strategies should be undertaken to reduce the climate impact of emissions from aviation and freight transportation.
4. Other greenhouse gases should be reduced in concert with CO_2 reductions.

Advanced Technology

1. Governments should have strong advanced technology programs that reflect clear sustainable development goals.
2. Programs should be designed to reduce conventional pollutants, greenhouse gases, toxics, and noise together, not one at the expense of the other.
3. These programs must have clear performance targets.
4. Such programs should not be a substitute for taking action in the short-term, but a complement.
5. Evaluation of technologies should consider:
   —Life-cycle analysis–including fuel and vehicle production and disposal,
   —Real-world performance over the full vehicle lifetime,
   —Whether the technology is inherently clean,
   —Potential for market saturation.
6. As technologies progress from research to development, their potential for commercialization should be emphasized. Safety, quality, and public acceptance are key factors.
7. Both standards and market incentives should be used to commercialize advanced technologies.
8. Government policies should encourage the introduction of incremental technologies as they are developed.
9. Programs to develop new technologies should be coordinated across jurisdictions to help develop economies of scale.

The rationale for each principle provided in this section was not developed in the Bellagio meeting. The Energy Foundation and consultant Michael Walsh prepared this section to better explain and illustrate the principles. Meeting participants approved the post-meeting preparation of the rationale, and reviewed this section before publication. Although the text is consistent with the discussions in the Bellagio meeting that surrounded each principle, readers should be aware that the explanatory text did not receive the word-by-word group scrutiny that the principles themselves received.

This section discusses each of the principles outlined in the preceding section.

Overarching Principles

1. *Clean vehicle strategies should promote air quality (including air toxics) and greenhouse gas goals in parallel. Noise pollution should be considered as well.*

   There are promising technology paths that will provide very low emissions of conventional pollutants, toxics, and greenhouse gases as well as low noise levels. These should take precedence over technology paths that lead to trade-offs among these goals. For example, fuel-cell technologies hold great promise for achieving all four goals, whereas diesel vehicles tend to provide low carbon dioxide emissions but increase noise, toxicity, and oxides of nitrogen (NOx) emissions.

2. *Vehicles and fuels should be treated as a system.*

   It has become increasingly clear as emissions regulations have become more stringent that fuel properties and vehicle technologies are closely intertwined. As described elsewhere in this document, certain fuel parameters such as lead or sulfur content must be controlled as a precondition to introducing advanced vehicle technologies. In addition, many other fuel properties, such as aromatic content and Reid Vapor Pressure, must also be controlled to enable maximum emissions reduction at lowest cost.

3. *New vehicle standards for greenhouse gas emissions and conventional pollutants should be fuel-neutral.*

With fuel and vehicle technology constantly evolving, it is wise for policy-makers to help shape this evolution by establishing fuel-neutral performance standards, or incentives based on performance standards, rather than by explicitly favoring a specific fuel or technology that appears most promising at the time.

Vehicles operating on different fuels frequently compete for the same market. In the past, governments have often set different standards for the different fuels, thereby introducing distortions into the marketplace and at the same time undercutting the goals of clean air or low greenhouse gas emissions. For example, if diesel-fueled and gasoline-powered cars compete in the same market, a more lenient NOx standard for the diesel cars gives them a competitive advantage, stimulates their sales, and undercuts the clean air targets that might otherwise be achieved.

4. *Policies should be based on full life-cycle emissions, including vehicle and fuel production, distribution, and disposal.*

In most major vehicle markets, air regulations cover "tailpipe emissions," post-combustion gases and particles expelled through the tailpipe, and "evaporative emissions," hydrocarbon gases that evaporate from the fuel tank, hoses, and other parts of the on-board fuel system. But there are other emissions associated with the use of any vehicle. Conventional air pollutants, air toxics, and greenhouse gases are also byproducts of fuel extraction, refining, transportation, and storage, as well as vehicle production and disposal. Together, these vehicle-related emissions are often termed "life-cycle" emissions.

In many countries, emissions associated with fuel production and distribution are controlled, in part, through separate regulations. For example, many jurisdictions limit emissions from oil refineries. A number of countries, particularly in Europe, have instituted Extended Producer Responsibility policies that are improving vehicle disposal practices. This piecemeal approach has successfully lowered emissions from the most polluting points in the life cycle, but the approach is likely to deliver sub-optimal results. This will be increasingly apparent as a wider diversity of propulsion and fuel technologies enter the market. For example, any evaluation of the environmental merits of a hydrogen fuel cell car would be meaningless unless it considered the source of the hydrogen. With such technologies emerging and analysts increasingly taking a life-cycle approach to emissions assessments, many air regulators recognize the importance of moving to a life-cycle approach to emissions regulations.

5. *Cost-effectiveness should be considered in achieving the goals.*
   Where alternative approaches exist to achieve the same environmental targets, the most cost-effective approach should prevail. Cost-effectiveness methodologies should consider life-cycle emissions of multiple pollutants and both near-term and long-term benefits.

6. *Economic instruments should be used to promote adoption of clean, efficient vehicles and fuels.*
   Experience, especially in Europe, has repeatedly demonstrated that economic instruments such as tax preferences can stimulate the early introduction of advanced vehicle and fuel technologies. For example, in the mid-eighties, Germany introduced unleaded gasoline and low-pollution catalytic converter technology much more rapidly than the rest of the Common Market by introducing tax incentives to make these options economically attractive. More recently, Hong Kong introduced a tax policy that made low sulfur (less than 50 ppm) diesel fuel cheaper at the pump than high-sulfur fuel; as a result, almost overnight the entire commercial diesel fuel market shifted to low sulfur. This shift has enabled Hong Kong to quickly proceed with a diesel retrofit program.

7. *Policies for clean vehicles should be mutually re-enforcing, not conflicting. For example, economic policy should support standards.*
   Conflicting policies can substantially undermine potentially effective programs. For example, the U.S. Corporate Average Fuel Economy (CAFE) program was put in place in the mid-1970s and resulted in tremendous fuel savings and lower greenhouse gas emissions. However, by the mid-1980s this program was being undercut by lower and lower fuel prices at the retail pumps, giving consumers less incentive to purchase fuel-efficient cars. The United States' policy of allowing heavier passenger vehicles, such as sport utility vehicles (SUVs), vans, and large pickup trucks, to meet less stringent CAFE standards and not applying the "gas-guzzler tax" to these vehicles further eroded the gains made by the CAFE program, as the U.S. fleet shifted to heavier, less efficient vehicles.

8. *Clean transportation strategies should promote inherently clean vehicles*

It has been well established over the past forty years that conventional vehicles and engine technologies can be cleaned up substantially in the laboratory. The in-use performance of these technologies has also improved tremendously. But all conventional control technologies are susceptible to failure, whether through driver behavior, system deterioration, inadequate design, or sabotage. When this happens, emissions can increase substantially, approaching or even exceeding uncontrolled levels. For example, in the U.S., a report recently released by the National Academy of Sciences notes that older and malfunctioning vehicles make up about 10 percent of the nation's fleet and typically emit about 50 percent of the most harmful air pollutants from motor vehicles.

It is impossible to meet air quality goals when a portion of the fleet operates with failed emissions control systems in high-polluting modes. Inspection and maintenance programs are important, but have limited success in keeping high-emitting vehicles off the road. Significantly, technologies exist or are emerging into the marketplace that do not have any high-polluting failure modes; electric cars are one example. These "inherently clean" technologies should be encouraged in both the light-duty and heavy-duty sectors.

9. *New vehicle industry in developing countries should be based on new technology, and not be a dumping ground for old technology.*

While the vehicle markets in Europe and North America are approaching saturation and are expected to have only marginal, if any, growth in the future, many rapidly industrializing countries (e.g., China and India) are experiencing very rapid growth in their vehicle registrations. Vehicles sold in these countries are typically more polluting and less efficient than comparable vehicles sold in already industrialized countries.

It costs very little to move from early control strategies to the most advanced (e.g., to move from Euro 1 to Euro 4 emissions standards), but the benefits are profound. Therefore, developing countries should hold vehicle manufacturers accountable for producing and selling the cleanest and most efficient vehicles possible considering available fuels and the existing infrastructure. For their part, manufacturers should inform the governments in these countries of changes needed (such as improved fuel quality) to allow them to offer the same vehicle technology as that available in developed countries.

10. *The recommendations in this paper also include vehicles and fuels that are especially important for developing countries (mopeds, tuk-tuks, buses, etc.).*

Many developing countries have unique vehicle categories that don't exist in significant numbers in developed countries (e.g., jeepneys in the Philippines or tuk-tuks in Bangkok) or exist in much lower proportions (e.g., two-stroke-engine motorcycles) and therefore have not received the same degree of pollution control attention as typical cars and trucks. Such vehicles often produce a significant portion of the pollution in a city's atmosphere. Governments should include these vehicles in their emission reduction strategies, and should note that the principles outlined in this document apply to these categories as well.

11. *A truly effective program will require the active involvement of governments at the national, regional, and municipal level.*

Different government organizations have differing roles and all are necessary to implement a truly comprehensive program. Generally, the national government is most effective at setting nationwide minimum requirements for new vehicles as well as minimum fuel properties required to allow advanced vehicle technologies. However, local conditions may call for local strategies. For example, advanced fuel controls or vehicle I/M programs may be best designed and implemented at the local level, albeit with national agency involvement. National governments also tend to be best suited to funding technology research and development, whereas successful pilot programs to demonstrate new technologies, even if supported by national funds, typically require the active participation of local agencies to be successful.

Fuels

1. *Lead should be immediately banned in all fuels.*

Over the past century, numerous clinical, epidemiological, and toxicological studies have defined the nature of lead toxicity, identified young children as a critically susceptible population, and explored the mechanisms of action of lead toxicity. Each molecule of lead has the potential to disrupt the chemical basis of normal cellular function. Lead affects many organs and organ systems in the human body, with subcellular changes and neurodevelopmental effects appearing to be the most sensitive. Available studies indicate consistently that children with lower blood lead levels have higher intelligence quotients (IQs) than children with higher lead levels.[8]

In addition to directly threatening public health, leaded gasoline precludes use of catalytic converters and closed-loop engine management systems (which depend upon oxygen sensors which are impaired by lead). Regions with leaded gasoline are therefore stuck with vehicles that emit unacceptably high levels of criteria pollutants and have poor fuel economy.

Because of the concerns highlighted above, a global consensus has emerged to phase out the use of lead in gasoline.[9,10] However, a number of countries continue to allow leaded gasoline, including Indonesia, Venezuela, Russia, and several African and Middle Eastern countries.

2. *Near-zero sulfur (10 ppm or less) should be introduced in all fuels except residual bunker fuel.*

   a. Use longer time horizon, but stricter targets.

   b. Do in one step, not more.

Having eliminated lead from much of the world's supply of motor fuels, many regulators now see near-zero sulfur levels as crucial to meeting air quality goals, and are aggressively reducing fuel sulfur levels. Sulfur in gasoline increases emissions of carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NOx) from all vehicles equipped with a three-way catalytic converter.[11] Sulfur in diesel fuel produces harmful sulfate particulate emissions. Sulfur also has a variety of negative effects on the most promising technologies for controlling NOx, particulate, and toxic emissions from diesel vehicles.

By contrast, low-sulfur fuels enable new technologies that can dramatically reduce emissions and improve efficiency, including advanced aftertreatment for diesel engines and gasoline direct injection. Furthermore, low-sulfur fuels enhance the retrofit opportunities for existing diesel vehicles, enabling them to achieve very low particulate emissions.

Regional and sector-specific requirements for low sulfur can result in higher sulfur content in unregulated fuels. Therefore, sulfur restrictions should be worldwide and must apply to both on- and off-road fuels.

While the goal of near-zero sulfur should apply in all countries around the world, the time frame for achieving this goal may vary from country to country depending on local conditions. Experience in countries that have been moving toward low sulfur levels in a series of steps indicates that countries new to sulfur regulation will probably find it more cost-effective to move to a near-zero sulfur level in a single step.

3. ***Sulfur content in residual bunker fuel and heavy fuel oil should be significantly reduced worldwide, particularly in sensitive areas.***

Current sulfur levels for diesel fuel used in on-road vehicles range from 5,000 ppm to less than 10 ppm. By contrast, sulfur levels in the residual fuel oils used to power ocean-going vessels are typically a staggering 30,000 ppm. And, there is some evidence that sulfur restrictions for on-road vehicle fuels result in excess sulfur being "dumped" into residual fuel oil, raising sulfur content for ship fuels even higher Whether dumping occurs or not, such extreme sulfur levels seriously degrades air quality at major ports. Even on the open seas, high sulfur emissions contribute to global aerosol formation, an important factor in global warming.

Further, to the extent that control of particulate matter (PM) and NOx from marine vessels is considered desirable both in coastal waterways and on the open sea, low-sulfur fuel will likely facilitate the use of the more advanced control technology.

4. ***Benzene levels in gasoline should be capped at no more than one percent worldwide. In addition, gasoline aromatic content should be controlled.***

The U.S. EPA recently reconfirmed that benzene[12] is a known human carcinogen by all routes of exposure. Respiration is the major source of human exposure. Long-term respiratory exposure to high ambient benzene concentrations causes cancer of the tissues that form white blood cells. Among these cancers are acute nonlymphocytic leukemia and chronic lymphocytic leukemia. Exposure to benzene and/or its metabolites has also been linked with genetic changes in humans and animals.

A number of adverse non-cancer health effects have also been associated with low-dose, long-term exposure to benzene. People with long-term exposure may experience damage to blood-forming tissues, especially bone marrow. This damage can disrupt normal blood production and decrease important blood components, such as red blood cells and blood platelets, leading to a number of serious blood disorders such as preleukemia and aplastic anemia. The most sensitive noncancer effect observed in humans is the depression of absolute lymphocyte counts in the circulating blood.

Lowering the benzene content in gasoline reduces the direct exposure to benzene emissions from evaporation (especially hazardous in enclosed garages) and vehicle refueling. Further, reducing the benzene and aromatic content of gasoline reduces tailpipe emissions of benzene. Reduced aromatics would also reduce smog.

5. *CNG, LPG, and other alternative fuels need clear content standards for environmental performance; these standards should be set at the beginning of a fuel's introduction.*

Variations in fuel composition can create higher emissions and poorer performance in vehicles designed to operate on that fuel. Therefore it is important to set the fuel specifications for any alternative fuel at the beginning of a fuel's introduction.

Conventional Pollutants and Toxics

1. *Emissions standards worldwide should be based on the best available technology.*

A relatively small number of companies produce most of the world's vehicles. 10 companies produce about 80% of all new cars. Each of these major companies produces vehicles which comply with the most stringent requirements in effect at any given time, in either Europe or the U.S. or Japan, and therefore are capable of installing the most advanced technologies on vehicles which they produce anywhere.

Further, virtually every country has areas which are severely polluted and which therefore need the cleanest vehicles and fuels possible.[13]

Finally, although diesel engine and vehicle manufacturers are more diverse than car manufacturers, after-treatment technologies such as particulate filters are available from global supplies and can be broadly applied to diesel vehicles to dramatically reduce the mass, number, and toxicity of particles.

2. *Future new vehicle standards should be fuel-neutral.*

Vehicles operating on different fuels frequently compete for the same market. In the past, governments have often set different standards for the different fuels, thereby introducing distortions into the marketplace and at the same time undercutting the goals of clean air or low greenhouse gas emissions. For example, if both diesel-fueled and gasoline-powered cars compete in the same market, a more lenient NOx standard for the diesel cars gives them a competitive advantage, stimulates their sales, and undercuts the clean air targets that might otherwise be achieved.

3. *Vehicles that perform the same function should be required to meet the same standards, based on the capability of the leader, not the laggard.*

For many years, the U.S. emissions standards for light trucks were more lenient than the emissions standards for cars. As a result of this market distortion, vehicle manufacturers developed a new vehicle type, which came to be known as a sport utility vehicle or SUV, that had much higher emissions and poorer fuel economy than the passenger cars that the SUVs replaced. SUVs and other types of light trucks now make up about 50 percent of new sales in the U.S. This has led to much higher emissions and fuel consumption from the passenger fleet than was intended.

To minimize these problems in the future, both the California Air Resources Board and the U.S. EPA recently adopted new rules that require all light-duty vehicles intended to be used for passenger transportation, from small cars to large SUVs, to meet the same stringent standards.

To prevent the emergence of high-polluting SUVs or other non-traditional passenger vehicles in other countries, similar regulatory approaches should be adopted worldwide.

4. *Vehicle standards and fuel standards should be linked.*

It has become increasingly clear as emissions regulations have become more stringent that fuel properties and vehicle technologies are closely intertwined. As described elsewhere in this document, certain fuel parameters such as lead or sulfur content must be controlled as a precondition of introducing certain vehicle technologies. In addition, many other fuel properties, such as aromatic content and Reid Vapor Pressure, must also be controlled to enable maximum emissions reduction at lowest cost.

5. *Particulate emissions standards should be designed to reduce the number of particles as well as the mass.*

Certain diesel particulate control technologies such as high-pressure fuel injection may actually increase the number of the very small "ultrafine" particles, even as they reduce total particulate mass. A rising tide of evidence indicates that these ultrafine particles may actually be more hazardous than the larger particles that are being reduced. Technologies exist which reduce both the mass and number of particles, and regulatory strategies should be designed to control both, thereby minimizing any health risk. For example, a study sponsored by the Manufacturers of Emissions Controls Association at Southwest Research Institute found that particulate filters substantially lower the mass of PM, the number of ultrafines, and the overall toxicity of diesel exhaust.[14]

6. *Test procedures should reflect real-world operating conditions for all vehicles and all engines.*
Because emissions vary widely during different modes of vehicle operation, it is important to reflect all modes in measuring and controlling emissions. Emissions regulations for all vehicles and engines are based on standardized test procedures meant to reflect typical real-world driving. Over the past 40 years it has become apparent that many, if not most, of the tests are inadequate; by failing to capture some types of real-world operation, they give an incomplete picture of real-world emissions and may lead manufacturers to employ inferior emissions control strategies.[15]

To minimize this problem, it is first of all necessary to adopt test procedures that are as representative and comprehensive as possible within the limitations of time and cost. Important elements of a good test protocol include transient operation and cold starts.

But, no single test procedure can cover all real-world operating conditions,[16] particularly where certification consists of an engine-based test procedure rather than a vehicle-based procedure, as is the case with heavy-duty engines.[17] The best way to ensure that test procedures cover the full range of driving conditions is with "not-to-exceed" (NTE) in-use limits.

The NTE approach establishes an area (the "NTE zone") under the torque curve of an engine where emissions must not exceed a specified value for any of the regulated pollutants. The NTE standard would apply under any conditions an engine could reasonably be expected to undergo in normal vehicle operation.[18] The U.S. EPA has adopted NTE limits for heavy-duty diesel engines. Such an approach could and should be expanded to cover all other vehicle and engine categories as well.

In addition to ensuring emission benefits over the full range of in-use operating conditions, NTE requirements make in-use compliance testing easier and more practical. A standard that relies on laboratory testing over a very specific driving schedule renders comparison of in-use test results with the standard more difficult. This is especially true when standards are based on engine tests (which is typical for heavy trucks, buses, and offroad equipment) since the engines have to be removed from the vehicle for in-use testing. Testing during normal vehicle use, using an objective numerical standard that is not cycle-dependent, makes enforcement easier and provides better estimates of real-world emissions than extrapolation from a fixed laboratory procedure.

7. *Inspection and Maintenance (I/M) programs should be used to control lifetime in-use vehicle emissions. Programs should separate inspection from repair, and post-inspection diagnostics should precede repair.*

Today's internal combustion engines rely on properly functioning emission controls to keep pollution levels low. Minor malfunctions in the emission control system can boost emissions significantly. Major malfunctions in the emission control system can cause emissions to skyrocket. A relatively small number of vehicles with serious malfunctions frequently cause the majority of vehicle-related pollution. Unfortunately, it is rarely obvious which vehicles fall into this category, as the emissions themselves may not be noticeable and emission control malfunctions do not necessarily affect vehicle drivability.

Three approaches have been developed to reduce, if not eliminate, emissions control deterioration in use: I/M programs, onboard diagnostics (discussed in the next two section), and, especially in California, the introduction of advanced, inherently clean technologies. (Inherently clean technologies are discussed within the Overarching Principles and mentioned in the Advanced Technology section.) But onboard diagnostics and inherently clean vehicles are relatively new and not yet employed in many areas of the world. Therefore, well-managed I/M programs are key to controlling in-use emissions.

Effective I/M programs identify problem cars and assure their repair. By encouraging good maintenance and discouraging tampering and misfueling, I/M remains the best demonstrated means for protecting a national investment in emission control technology and achieving the desired air quality gains.

Experience with a range of I/M program designs over many years has consistently shown that centralized, test-only inspections have advantages over combined test-and-repair programs. Furthermore, good diagnosis of the causes of I/M emissions failures should precede repairs. The best way to assure this is to have an independent body diagnose the problems before repairs begin.

8. *On-Board Diagnostics (OBD) that identify failure modes and store failure data should be required for all new vehicles.*

Almost all new vehicles produced in the world today are equipped with on-board computers, which monitor and control a variety of functions on the vehicle. These computers are capable of collecting and storing information that tracks the emissions control performance of critical emissions control components. Such OBD systems are required in many countries but should be required on all new vehicles in every country.

In addition to identifying problems that result in high emissions, OBD systems assist mechanics in identifying the causes of the problem, thus assuring higher quality and more focused repairs.

OBD systems are inexpensive and more than pay for themselves in lower repair costs and better fuel economy over the life of a vehicle.

9. *On-board measurement with real-time logs should be required for all new vehicles.*

New sensors have been developed which could, in conjunction with on-board computers, monitor actual emissions from vehicles as they are operating. The computer could collect and store this information and could also alert the driver when repairs are needed. Such systems have not yet been required in any country, but should be required on all new vehicles in every country.

OBM technology is emerging rapidly and can be just as low-cost and cost-effective as OBD systems.

10. *Manufacturers should be responsible for in-use (real-world) emissions in normal use.*

Vehicle and engine manufacturers are required in most countries to obtain a certification or type approval before vehicle production begins; this should only be the starting point for their responsibilities. It is not emissions in the laboratory but emissions on the road that affect air quality. Therefore manufacturers should be responsible not just for the design of systems that work under laboratory conditions, but also for producing systems that achieve the same low emissions under normal driving conditions over the full life of the vehicle as long as the vehicle is maintained according to the manufacturer's recommended specifications.

11. *Regulators should focus on in-use testing of heavy-duty vehicles.*

As noted above, it is emissions under actual driving conditions that affect air quality. Unfortunately, in recent years several heavy-duty engine manufacturers designed and sold systems that were virtually uncontrolled in actual highway driving even though they met standards in the laboratory. One reason for this is that in-use testing of heavy-duty engines has received very little priority. The best way to assure low in-use emissions is to let the industry know that they will be held accountable, and to follow up with in-use testing. The NTE provisions described previously are one way to make this much easier in the future. In-use testing is likely to be especially important in the near future as new aftertreatment technologies are added to heavy trucks and buses for the first time.

12. *Cost-effective retrofit programs should be established for all vehicles.*

a. Retrofit standards must be matched by appropriate fuel standards (e.g., low-sulfur, no-lead gasoline).

b. Testing must be done to verify efficacy of retrofit programs.

New vehicle and fuel standards are central to any national strategy to reduce vehicle emissions. However, existing vehicles will be on the road for many years and one way to reduce emissions is to encourage or require the retrofitting of these vehicles to cleaner configurations, for example by installing catalysts or particulate filters.

Successful programs have been carried out with both gasoline and diesel vehicles. These programs provide useful lessons in the promise and pitfalls of retrofit programs. For example, to be successful, such programs must assure that fuel of the appropriate quality is available and used. In addition, an in-use verification program must be carried out, with the retrofit supplier responsible for any failures. Regulators interested in developing new retrofit programs should investigate prior programs to ensure success.

13. *Scrappage and other policies should be used to speed fleet turnover.*

An alternative to retrofit programs for older, high-polluting vehicles is to encourage or require that such vehicles be taken off the roads and scrapped. Small- and large-scale scrapping programs have been carried out in a number of countries with varied success. Great care must be taken to assure that the vehicles are actually destroyed and that payments are made only for vehicles which otherwise would be driven.

1. *Measures to reduce greenhouse gas emissions from all vehicles (including at least 25 percent average reduction for new personal passenger vehicles over the next decade) should be adopted. Mechanisms could include 1) voluntary agreements with manufacturers, 2) fuel efficiency standards, 3) tailpipe greenhouse gas standards, and 4) financial incentives.*
Motor vehicles are a major source of carbon dioxide, the chief greenhouse gas. Any serious effort to stabilize atmospheric concentrations of greenhouse gases must significantly reduce carbon dioxide emissions from motor vehicles.

By means of a voluntary agreement with car manufacturers to reduce CO_2 emissions from new vehicles by 25 percent by 2008 compared to 1995, the European Union (EU) has demonstrated clear leadership in this area. Light-duty vehicle manufacturers in all other countries should achieve at least this percentage reduction by 2010 compared to a 1995 baseline. It should be noted that new 1995 European vehicles were already more efficient than new vehicles sold in most countries, so for many non-European countries a 25 percent improvement is a relatively modest goal. As the global fleet grows and carbon dioxide continues to accumulate in the atmosphere, greater and greater per-vehicle reductions will be needed.

2. *Reduction measures should be designed to avoid promoting increases in size, weight, or power.*
Many technologies have been developed over the past decade that could have been used to improve either fuel economy (thereby reducing greenhouse gas emissions) or vehicle performance. In most cases they have been used for performance. In the U.S. passenger vehicle fleet, for example, between 1988 and 2001 average horsepower increased by 53 percent, acceleration by 18 percent and weight by 19 percent while fuel economy declined by 8 percent. The U.S. EPA has estimated that the technology improvements that enabled these increases could have been used instead to increase new vehicle fuel economy by 20 percent over the same period.

While tighter standards would have employed some of the new technologies to further improve fuel economy, the U.S. experience points to a subtler lesson. The chief reason fuel economy has declined in the U.S. in recent years is that sales of larger vehicles, such as SUVs and minivans, have exploded and now account for about 50 percent of all new passenger vehicle sales. Because U.S. fuel economy standards allow these heavier vehicles to be less fuel-efficient than passenger cars, the result has been declining fleet-wide fuel efficiency.

The lesson to be learned is that, although there may be some technical justification for allowing larger, heavier, more powerful vehicles to be less fuel-efficient, policy-makers must be wary of unintended consequences. Fuel economy or greenhouse gas emissions standards that vary by engine or vehicle size can create loopholes or perverse incentives that allow overall motor fuel consumption to increase even though per-vehicle fuel economy is controlled.

3. *Effective strategies should be undertaken to reduce the climate impact of emissions from aviation and freight transportation.*

Air traffic is growing faster than any other transportation sector, and its greenhouse gas emissions are especially damaging because they are emitted high in the atmosphere. A special report from the Intergovernmental Panel on Climate Change (IPCC) examined the effect of aviation on the global atmosphere. In one IPCC scenario, aviation was projected to produce roughly 15% of the climate-changing effect of all human-caused greenhouse gas emissions by 2050. Other scenarios had lower, but still significant impacts. Road freight transport is another fast-growing sector that must be addressed by programs to reduce greenhouse gases

4. *Other greenhouse gases should be reduced in concert with CO_2 reduction.*

Beyond CO_2, other significant greenhouse gases include methane, nitrous oxide, water vapor, tropospheric ozone, and chlorofluorocarbons (CFCs), which together have a "forcing" on climate change approximately equal to that of carbon dioxide. Man-made sources of methane, nitrous oxide, and ozone have resulted in substantially increased concentrations in the atmosphere in the 20th century, although each of these gases also has natural sources. CFCs are entirely a result of human activity. Motor vehicles contribute significantly to concentrations of nitrous oxide, CFCs, and tropospheric ozone. Nitrous oxide (N_2O) emissions are substantially higher with catalyst-equipped cars compared to non-catalyst cars. Fortunately, the N_2O levels from more advanced catalyst cars are lower than levels from the first generation. It may be necessary to tighten N_2O requirements in the future.

Most recently, evidence indicates that black carbon (soot), a primary constituent of diesel exhaust particulate, may be absorbing heat and thereby contributing to global warming. As noted by U.S. National Aeronautics and Space Administration's Dr. James Hansen, "Black carbon reduces aerosol albedo, causes a semi-direct reduction of cloud cover, and reduces cloud particle albedo."[19] A reduced albedo means Earth's atmosphere retains more solar energy, contributing to global warming. Similarly, Dr. Mark Jacobson of Stanford University states in the February 8, 2001 volume of *Nature* that black carbon may be the second most important component of global warming after CO_2, responsible for perhaps 15 to 30 percent of global warming.

Advanced Technology

1. ***Governments should have strong advanced technology programs that reflect clear sustainable development goals.***

   It seems likely that sustainable development goals will include very substantial reductions in both conventional pollutants and greenhouse gases from the transportation and other sectors. These reductions will need to take place in a context of rapid growth in the number of vehicles and the vehicle kilometers driven. Governments therefore need to stimulate the development of advanced technology vehicles and renewable fuels that have zero or near-zero emissions of conventional and greenhouse pollutants. Advanced vehicle development should also be guided by other sustainable development priorities, such as improving safety and reducing consumption of raw materials.

   Programs might include standards, direct Research and Development (R&D) investment, financial incentives, and/or public-private partnerships.

2. ***Programs should be designed to reduce conventional pollutants, greenhouse gases, toxics, and noise, not one at the expense of the other.***

   Technology paths exist that ultimately provide very low emissions of conventional pollutants, toxics, and greenhouse gases as well as low noise levels. These should take precedence over technology paths that lead to trade-offs among these goals. For example, fuel-cell technologies hold great promise for achieving all four goals whereas diesel vehicles tend to produce low greenhouse gas emissions but increase noise, toxicity, and NOx emissions.

3. *These programs must have clear performance targets.*

Experience has shown that the most effective programs have clear targets with easily monitored interim milestones. For example, the recent EU/ACEA fuel economy agreement has a clear target of 25% reduction in CO_2 emissions from 1995 levels by 2008 with interim milestones in 2003.

The importance of designing these performance targets to address multiple goals (per the previous principle) is illustrated by the U.S. Partnership for a New Generation of Vehicles (PNGV) program, which has strong fuel efficiency goals but has suffered from inadequate emissions goals. As a result, many of the prototype vehicles that have been developed may have difficulty meeting the newest emissions standards, rendering them unmarketable, and many environmental groups oppose continuation of the program.

4. *Such programs should not be a substitute for taking action in the short-term, but a complement.*

Clearly, effective programs to improve air quality and reduce greenhouse gas emissions will combine near-term measures that take advantage of the best technologies widely available with longer-term programs designed to produce new vehicles and fuels that come ever closer to truly sustainable technology. Technology development programs must not be an excuse for weak near-term standards; experience has shown over and over that betting on–and waiting for–"perfect" technological solutions is unwise.

5. *Evaluation of technologies should consider:*

—Life-cycle analysis–including fuel and vehicle production and disposal.
—Real-world performance over the full vehicle lifetime.
—Whether the technology is inherently clean.
—Potential for market saturation.

In evaluating or setting performance targets for future technologies, decision-makers should not be constrained by current methods of vehicle regulation. Evaluation methods that best support societal objectives, such as full life-cycle analysis of impacts, should be employed. And, of course, the benefits of various technologies should be compared in the context of expected market penetration; a super-clean and efficient vehicle that works in niche markets and a somewhat less clean and efficient vehicle that is more broadly marketable may be equally desirable.

6. *As technologies progress from research to development, their potential for commercialization should be emphasized. Safety, quality, and public acceptance are key factors.* Some beneficial technologies, such as integrated starter-generators, transition easily from the R&D phase to commercialization. Other technologies, such as hydrogen fuel cell vehicles, face a variety of obstacles in moving beyond the prototype phase. As technologies approach commercialization, policy-makers should focus on those that have strong potential for market success. However, governments should not shy away from instituting bold policies where appropriate to help especially promising technologies clear initial obstacles.

   Two of the most consistently apparent obstacles to new technologies are higher capital cost during a start-up phase, where sales volumes are low and manufacturers are still learning how to reduce costs, and, when the technology requires a special fuel, insufficient fueling infrastructure. Overcoming these obstacles will typically require substantial public investment. Policy-makers should compare the expected cost of such investments to the benefits offered by the new technologies and be prepared to push for appropriate public investments and investment mechanisms.

7. *Both standards and market incentives should be used to commercialize advanced technologies.* Experience, especially in Europe, has repeatedly demonstrated that economic instruments such as tax preferences can stimulate the early introduction of advanced vehicle and fuel technologies. For example, in the mid-eighties, Germany introduced unleaded gasoline and low-pollution catalytic converter technology much more rapidly than the rest of the Common Market by introducing tax incentives to make these options economically attractive. More recently, Hong Kong introduced a tax policy that made low sulfur (less than 50 ppm) diesel fuel cheaper at the pump than high-sulfur fuel; as a result, almost overnight the entire commercial diesel fuel market shifted to low sulfur. This shift has enabled Hong Kong to quickly proceed with a diesel retrofit program.

   Standards can also be designed to bring forward leading-edge technologies. California's Zero-Emission Vehicle (ZEV) program, which requires a percentage of each major automaker's new sales in California to have zero emissions, has arguably been the single most important driver worldwide for battery-electric, hybrid-electric, and fuel cell vehicle technologies.

8. *Government policies should encourage the introduction of incremental technologies as they are developed.*

One of the important elements of the Partnership For A New Generation of Vehicles (PNGV) in the U.S. was a provision that called on the vehicle industry to introduce incremental fuel efficiency improvements as advances were developed. Unfortunately, this provision was ignored in practice and has been one of the notable failures of the program. Rather than improve fuel economy, many of the technological advances were used instead to increase power or performance. The lesson is that clear and firm policies calling for incremental improvements must be an integral part of any longer term strategy or program.

9. *Programs to develop new technologies should be coordinated across jurisdictions to help develop economies of scale.*

As new technologies develop they will inevitably be relatively expensive compared to mature technologies that are being mass-produced in the millions. Efforts to coordinate early introduction of advanced technologies across many jurisdictions will introduce economies of scale, which will help reduce prices.

Principles must lead to real-world results. Although meeting participants agreed on the Bellagio principles as individual experts, not on behalf of any participants' organization or country, all indicated a willingness to work toward embodiment of these principles in new policies and programs. Emphases, methods, and degree of international coordination will vary from country to country. Participants associated with government agencies also expect to promote regular reporting on progress compared to the Bellagio principles.

The Energy Foundation intends to follow through on these principles, and may reconvene the Bellagio group within the next two years. Future meetings would likely expand participation to include additional countries, and would prioritize, and possibly refine, the 43 principles.

Preamble

1

Member countries of the Organization for Economic Cooperation and Development are listed at http://www.oecd.org.

2

Analysis performed by Michael P. Walsh.

3

Diesel exhaust particulate is currently understood to be the most problematic of the toxins emitted by motor vehicles. Significantly, the California Air Resources Board formally identified particulate emissions from diesel fueled engines as toxic air contaminants in August 1998, triggering the development of California's diesel risk reduction program. Other harmful toxins from vehicles include benzene, 1,3-butadiene, and formaldehyde.

4

The latest reports from the International Panel on Climate Change project that global temperatures could rise by as much as 5.8 degrees Celsius (10.5 degrees Fahrenheit) and sea levels by as much as 86 centimeters (34 inches) over the next century. The results of new models also persuaded the panel to declare unequivocally for the first time that human activity is responsible for global warming. Climate change will have serious impacts on the supply and distribution of freshwater resources and food crops. Among other impacts, vulnerable ecosystems will disappear or migrate, and local biodiversity may decline in some areas. Sea level rise is likely to cause the loss of some low-lying coastal areas and islands.

5

Based on comparison of average new vehicles in the U.S. with vehicles certified to California SULEV or U.S. Bin 1 standards.

6

Representation from the United States included regulators from the federal government and from the state of California, which retained unique authority to establish its own motor vehicle program after becoming a world leader in pollution control in the 1960s.

Rationale

7

See, for example, "The Cost of Emission Controls: Motor Vehicles and Fuels," a presentation made by Mr. Tom Cackette, Deputy Executive Director of the California Air Resources Board, at the Massachusetts Institute of Technology, July, 1998.

8

Case Studies in Environmental Medicine: Lead Toxicity, U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/HEC/caselead.html.

9

U.S. EPA (1986) *Ambient Air Quality Criteria Document for Lead,* Research Triangle Park NC: EPA ORD; U.S. Centers for Disease Control (1991) *Preventing Lead Poisoning in Young Children,* Atlanta: U.S. Department of Health and Human Services; C. Howson and Avila M. Hernandez (1996) *Lead in the Americas,* Washington: NAS Press; International Program on Chemical Safety (IPCS) (1995) *Environmental Health Criteria Document: Lead,* Geneva: IPCS, World Health Organization; National Research Council (1993). *Measuring Lead Exposures in Infants, Children and Other Sensitive Populations,* Washington: NAS Press.

10

In December 1994, at the Summit of the Americas, heads of state from a number of countries pledged to develop national action plans for the phase out of leaded gasoline in the Western Hemisphere. In May 1996, the World Bank called for a global phase out of leaded gasoline and offered to help countries design feasible phase out schedules and incentive frameworks. A key recommendation of the Third "Environment for Europe" Ministerial Conference held in Sofia, Bulgaria in October 1995 called for the reduction and ultimate phase out of lead in gasoline. In June 1996, the second United Nations Conference on Human Settlements, called Habitat II, included the elimination of lead from gasoline as a goal in its agenda. In May 1997, environmental ministers from the Group of Seven plus Russia endorsed the phase out of leaded gasoline in the 1997 Declaration of Environmental Leaders of the Eight on Children's Environmental Health.

11
For cars without a catalytic converter, the impact of sulfur on emissions is minimal; however for catalyst equipped cars, the impact on CO, HC and NOx emissions can be substantial. As noted by the U.S. Auto-Oil study, "The regression analysis showed that the sulfur effect (lower sulfur resulting in lower emissions) was significant for HC on all ten cars, for CO on five cars, and for NOx on 8 cars. There were no instances of a statistically significant increase in emissions." Based on the auto/oil study, it appears that NOx emissions fall about 3% per 100 ppm sulfur reduction for a typical catalyst equipped car. The situation is even more critical for advanced low pollution catalyst vehicles. Operation on typical U.S. conventional gasoline containing 330 ppm sulfur will increase exhaust HC and NOx emissions from new U.S. vehicles (on average) by 40 percent and 150 percent, respectively, relative to their emissions with fuel containing roughly 30 ppm sulfur.

12
Benzene is an aromatic hydrocarbon that is present as a gas in both exhaust and evaporative emissions from motor vehicles. Benzene in the exhaust, expressed as a percentage of total organic gases, varies depending on control technology (e.g., catalyst and type of catalyst) and the levels of benzene and other aromatics in the fuel, but is generally about three to five percent. The benzene fraction of evaporative emissions depends on control technology and fuel composition and characteristics (e.g., benzene level and the evaporation rate) and is generally about one percent.

13
It is, of course, the responsibility of the local government to assure that appropriate fuel is provided so that the advanced vehicle technology performs properly.

14
Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels, Final Report, Manufacturers of Emission Controls Association, Washington, D.C., June, 1999.

15
The test procedure problem has been compounded by the tendency of manufacturers to develop pollution control systems that are optimized for good performance in the laboratory under the specified test conditions but tend to be much less effective under real world driving.

16
Historically, the typical approach to setting emission standards has been to establish a numerical emission standard on a specified test procedure and rely on the prohibition of defeat devices—devices that reduce or eliminate the performance of emission control devices or systems under actual driving conditions—to ensure in-use control over the range of operation not included in the test procedure. However, the defeat device prohibition is not a quantified numerical standard and does not have an associated test procedure. As a result, the current focus is on a standardized test procedure, making it harder to ensure that engines will operate with the same level of control in the real world as in the test cell.

17
For example, the same engine used in both a 9,000-pound and a 15,000-pound vehicle would likely see much higher loads, on average, in the 15,000-pound vehicle, and therefore have higher emissions in use.

18
In addition, EPA has decided that the whole range of real ambient conditions must be included in NTE testing.

19
"Global Warming in the 21st Century: An Alternative Scenario," James Hansen, NASA Goddard Institute for Space Studies Research April, 17, 2001. www.giss.nasa.gov/research/impacts/altscenario/

Design: Conrad Jorgensen Studio
Editing: Evan Elliot
Printing: H. MacDonald Printing
Printed with vegetable-based inks on recycled paper.
This document can be downloaded at
www.ef.org/bellagio

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